Geospatial Analysis and Modelling of Urban Structure and Dynamics

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Foreword by Michael Batty

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Foreword

A Coming of Age: Geospatial Analysis and Modelling in the Early Twenty First Century

Forty years ago when spatial analysis first emerged as a distinct theme within geography's quantitative revolution, the focus was largely on consistent methods for measuring spatial correlation. The concept of spatial auto-correlation took pride of place, mirroring concerns in time-series analysis about similar kinds of dependence known to distort the standard probability theory used to derive appropriate statistics. Early applications of spatial correlation tended to reflect geographical patterns expressed as points. The perspective taken on such analytical thinking was founded on induction, the search for pattern in data with a view to suggesting appropriate hypotheses which could subsequently be tested. In parallel but using very different techniques came the development of a more deductive style of analysis based on modelling and thence simulation. Here the focus was on translating prior theory into forms for generating testable predictions whose outcomes could be compared with observations about some system or phenomenon of interest.

In the intervening years, spatial analysis has broadened to embrace both inductive and deductive approaches, often combining both in different mixes for the variety of problems to which it is now applied. Moreover, the focus has become more explicitly geographical although the term spatial still has a wider usage for many of the statistics and models that form the arsenal of techniques in this area are applicable to spatial systems other than the obvious geographies – such as ecologies, climatic regimes, and even astronomies. In this collection of papers, however, the authors use the term "geospatial" to ground their systems of interest geographical conceptions of cities and regions, but they also show how many of the advances over the last 40 years are now part of the background knowledge that constitutes this field. In fact, the concerns here are with major extensions of analysis and modelling which reflect new themes in geographical thinking that are resulting from changes in our perceptions of city systems. These are largely due to demographic, technological and behavioural change which are driving new problems and the need for new methods, as well as the enormous

changes that have taken place in our ability to collect, process and visualise digital data.

The way the editors have put together these chapters which are drawn from a wide and active community of scholars, reflects these concerns. The themes developed are based on new ways of data capture leading to data analysis orders of magnitude larger than anything hitherto in this field and at even finer scales, new ideas about the intrinsic complexity of the systems that we are dealing with and the limits to prediction, agent-based models of how individuals move and perceive their environments which are reflected in new ideas about transportation systems and new idea about measuring nearness in terms of accessibility, and new ways of incorporating time and dynamics in our models. The treatment is set of course against a background where the media for analysis and modelling is ever more visual and is fast moving from the desktop to the web and thence into real time contexts, unimaginable even when computers had become all pervasive by the mid 1990s.

It is worth elaborating several of these themes which emerge from the various chapters as they illustrate how standard theory and analysis is being supplemented by new ideas. Omer for example, shows how the long standing problem of spatial aggregation, often referred to as the "ecological fallacy" or the "modifiable aerial unit problem" influences and distorts our interpretation of the way space divides up, in his case residential segregation in the Israel town of Jaffa. His work blends issues about perception with the resolution at which the analysis takes place. Kostakos tackles the perception problem in a different way, building on movement patterns at an equally fine scale, involving the methods of space syntax, but showing how new technologies based on data capture using mobile phones can enrich our entire understanding of local space and its analysis. In some senses, these first two papers in the book point directions to a world of immensely rich data that analysts in this field will have to grapple with in the very near future, and the techniques developed are amongst the first rudimentary tools that will be needed as this new world enfolds. These are given real substance in the chapter by Laube and his colleagues where the notion of decentralised spatial computing in real time environments is demonstrated with respect to accessing location-based services that depend on high quality mapping databases.

A second theme dominating our thinking about city systems involves their complexity. Cities like most human systems can be understood on many levels and although it sounds extreme, every individual will perceive this complexity differently. This is in and of itself the very definition of what complexity means. Nevertheless, progress is being made in mapping structures of complexity, and in the last decade, network science has been revived to make sense of such structures through notions of hierarchy and scaling. Blumenfeld–Lieberthal and Portugali develop a simple but effective agent-based network model of city growth that generates the classic scaling of city sizes that mirrors Zipf's well-known rank size rule while Chen takes a different perspective, embedding fractal scaling of city sizes into Christaller-like central place hierarchical

structures. This again demonstrates a really nice feature of this book where many of the authors illustrate that the current frontier is built on the older foundations of spatial analysis and location theory, notwithstanding the massive variety that now characterise developments in this and similar fields.

The editors here draw a fine line between methodological and domain-based knowledge and this is nowhere clearer than in the general area of transportation analysis and modelling. Network structures, agent-based models, and real-time allocation in terms of location-based services are developed for a series of different transportation examples. Martens and colleagues develop a very innovative agent-based model for parking in real-time contexts using a car-following allocation scheme. Chaker, Moulin and Theriault develop a much larger scale application for simulating travel activities and set this in a virtual urban environment. Omer and Jiang examine segregation in street networks, again for the town of Jaffa using Atkin's Q-analysis which reflects a bipartite topological network approach providing an alternative and different view of residential segregation. Lu and her colleagues examine the perceptions of levels of transport service in Beijing from survey data while Mandloi and Thill extend their analysis of transport networks from the street to the building, illustrating how routing problems need to be considered across many scales. In all these chapters, resolution, scale, networks and cognition figure strongly, impressing once again the importance of the new themes generated in these various contributions.

The other profound change in this field has been the widespread underpinning of spatial analysis with GIS and remote sensing. Many of the chapters here use GIS as an enabling technology but GIS continues to have a major effect on the types of models and analytical techniques that are being developed. Combined with the continuing focus on urban growth, particularly in the developing world, various models have been developed which are closely linked to GIS and to the simulation of land use change, often supported by data that is sensed remotely. This domain of applications blends cellular automata with pattern analysis, often originating from ecology as Chen and her colleagues demonstrate for Greater Toronto. Integrating these styles of analysis and simulation is another important area of research as Yang illustrates in an analysis of growth in the Atlanta metro area. Research of considerable importance that is likely to see many more applications in the next decade as climate change becomes ever more significant are simulations of the urban water cycle as presented by Shepherd and his team. In examining urban change, techniques for smoothing spatial data are important in deriving consistent interpretations as Varanka shows, while embedding all these kinds of growth process in more formal space-time frameworks with appropriate ontologies is addressed by Yao.

Most of the contributions collected here have obvious policy relevance and some directly link analysis and modelling to policy questions. Urban complexity and form are issues addressed by Pagliardini and his colleagues who develop the "city as organism" argument in a spirited essay on what they

call “urban seeding”, which they argue represents a much more careful and less intrusive paradigm for urban planning and design than anything adopted hitherto. Besides urban form, spatial differences in disease and treatment increasingly occupy an important place in spatial analysis and Mu, Wang and McLafferty illustrate how important spatial relations, adjacencies and correlations are to the interpretation of cancers at different spatial scales, once again involving issues involving aggregation. Accessibility issues and the relationship to prices are crucial to questions of housing market provision and efficiency with Hwang and Thill providing an excellent demonstration of how careful spatial econometrics can be used to unravel complex effects. Efficiency versus equity are issues that Horner and Widener examine spatially in the provision of disaster relief while methods of aggregation, geographical weighting, and locality are explored by Wheeler in a visual analysis of spatial pattern, providing essential diagnostics for both interpretation and the construction of spatial policies.

The contributions in this book present an excellent profile of the state of geospatial analysis and modelling after the first decade of work in the twenty first century. Compared to 10 years ago, there are now some really explicit drivers to this field which are picked up and exploited here. Amongst the many origins and themes, new ways of capturing data digitally at the individual level, the development of systems based around networks (of which spatial locations are a subset), the notion of linking hierarchy to networks to morphology as in complexity theory, and the development of new ways of integrating diverse urban processes through simulation paying careful attention to the basic econometric and statistical principles of spatial analysis, are all represented here. Jiang and Yao do a great job in both selecting a comprehensive range of papers while at the same time, emphasising these key themes. Readers will enjoy what follows and the book will provide both a pointer to the field and an inspiration for further research.

London Michael Batty

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The International Cartographic Association Commission on Geospatial Analysis and Modeling, and the NordForsk funded Nordic Network in Geographic Information Science provide international platforms for networking active researchers in this dynamically evolving field of geographic information science. Both University of Gävle and University of Georgia, in particular the division or department with which we have been closely working, provide us friendly yet stimulating working environments.

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Pietro Pagliardini is an architect and urbanist born in Arezzo, Italy. As senior partner of Pagliardini, Rupi, Andreoni & Gazzabin Architecture Studio he has designed social housing and completed the design of over 1000 dwellings and over 50 industrial buildings. He participated in the preliminary phases of 17 different Integrated Plans for mixed-use social and private housing throughout Italy, and planning three of those neighborhoods. For the project in Arezzo he was also responsible for the architectural design. In an important architectural competition for the reconstruction of the historic city center of Arezzo, Italy, he collaborated with world-famous New Urbanists Léon Krier and Peter Calthorpe. Again with Léon Krier as consultant and Peter Calthorpe as supervisor working for the Arezzo Town Council, Pagliardini created the urban plan for social and private housing for the rural village of Vignale, studying and applying local building typologies. Pagliardini has spearheaded the movement to rediscover traditional Italian urbanism, coordinating various

groups already working in that direction previously working in isolation. He has been influential in alert-ing the government to these possibilities, appearing on public discussions with important politicians such as Vittorio Sgarbi, and arguing for the value of preserving historic built heritage.

Sergio Porta architect, Ph.D. is assistant professor at the Milan Politechnic, Italy, and adjunct professor at the King Fahd University of Petroleum and Minerals in Dhahran, Saudi Arabia. In Milan he is director of the Human Space Lab, which is currently involved in street design schemes and applied research in Italy and abroad. Dr. Porta is coordinator of an international network of space analysis and design named UStED – Urban Sustainability through Environmental Design, and is a member of ESRG – Environmental Structure Research Group. Dr. Porta also works as a consultant on architectural design and urban planning in Milan and Reggio Emilia, focusing on the social dimension of architecture and public space design. Dr. Porta was a visiting scholar at the Institute of Govern-mental Studies of the University of California at Berkeley, and is an associate researcher at the Institute for Sustainability and Technology Policy at Murdoch University in Perth, Western Australia, where he teaches a short course on sustainable urban design. Dr. Porta's latest research is oriented towards sustain-able/human/adaptive urban analysis and design, ranging from GIS-based space analysis to sustainable community design, transportation planning, and traffic calming techniques, to strategies for safety and livability in the public scene.

Juval Portugali is a professor of Geography at the department of Geography and the Human Environment, Tel Aviv University. He is the founder and head of the ESLab (Environmental Simulation Laboratory), the Porter School of Environmental Studies, founded at Tel Aviv University in 2001, head of the Environment and Society Graduate Program. He holds Ph.D at the Department of Geography, The London School of Economics and Political Sciences. He specializes in theories of complexity and self-organization related to agent-based modeling, urbanism, socio-spatial change, cognitive maps and spatial archaeology. Current research includes (i) The city as a complex self-organizing system. 2D and 3D cellular automata and agent base urban simulation models. (ii) Inter-representation nets and the construction of cognitive maps. His recent books include: Complex Artificial Environments, Springer Complexity Series, 2005 (Ed.); Self-Organization and the city, Springer, 2000; The Construction of Cognitive Maps, Kluwer Academic Publishers, Dordrecht, 1996 (Ed.); Implicate Relations: Society and space in the Israeli-Palestinian conflict, Kluwer Academic Publishers, 1993.

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University of Texas at San Antonio, and is also on the architecture faculties of universities in Holland, Italy, and Mexico. He designed the Commercial Center in Doha, Qatar in collaboration with Hadi Simaan and José CorneliodaSilva. Dr. Salingaros' theoretical work under-pins and helps to link new movements in architecture and urbanism, such as New Urbanism, the Network City, Biophilic Design, Self-built Housing, and Sustainable Architecture. He is working with the Peer-to-Peer Foundation to promote self-built housing for the developing world. Dr. Salingaros collaborated with Christopher Alexander, helping to edit the four-volume "The Nature of Order" during its 25-year gestation. In recognition of his efforts to under-stand architecture using scientific thinking, he was awarded the first grant ever for research on architecture by the Alfred P. Sloan Foundation, in 1997. Dr. Salingaros is a member of the INTBAU College of Traditional Practitioners, and is on the INTBAU Committee of Honor. Dr. Salingaros was included as one of the "50 Visionaries" selected by the UTNE Reader in 2008.

Willis Shem has just completed a 1-year appointment as a Lecturer in Meteorology in the department of Geology, Geography and physics at the University of Tennessee in Martin. Prior to that he was a post-doctoral research associate in the department of Geography at the University of Georgia. His research work at the University of Georgia was mainly on the impact of urbanization on the precipitation component of the hydrological cycle with focus over the Atlanta region. Part of this work was recently (2009) published in the "Atmospheric Research" Journal. Dr. Shem has made several presentations in conferences organized by the American Meteorological Association (AMS) and Association of American Geographers (AAG) and has membership in both organizations. Dr. Shem has a multi-disciplinary background having received his BS (Meteorology) from Nairobi University (Kenya), MEng. (Water Resources Technology) from Vrije Universiteit Brussels (Belgium) and PhD (Earth and Atmospheric Science) from Georgia Institute of Technology (USA). Dr. Shem re-joined the University of Georgia starr in the summer of 2009 as a post-doctoral researcher.

J. Marshall Shepherd is an associate professor of geography/atmospheric sciences at the University of Georgia. He conducts research, advising, and teaching in atmospheric sciences, climatology, water cycle processes and urban climate systems. Prior to joining the UGA faculty, Dr. Shepherd spent 12 years as a research meteorologist at NASA. Dr. Shepherd was also Deputy Project Scientist for the Global Precipitation Measurement (GPM) mission. For his work on urban climate, Dr. Shepherd was honored in 2004 at the White House with the Presidential Early Career Award for pioneering scientific research. Dr. Shepherd is a Fellow of the American Meteorological Society and has over 50 publications (refereed articles, book chapters, reports). Dr. Shepherd has served on the American Meteorological Society (AMS) Executive Council and as contributing author on the 2007

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Marius Thériault is geographer and full professor at the Graduate School of Land Planning and Regional Development (ESAD), Laval University, Québec, Canada. Since 1979, he was teaching geographical information science, spatial analysis, applied statistics, geo-simulation, transportation and applied computing. He was Director of the Land Planning and Regional Development Research Centre at Laval University, from 2000 to 2006. He is also member of the Research Centre in Geomatics at Laval University. He is involved in several research networks (including GEOIDE), multi-disciplinary research projects and peer reviewed journals in Canada and Europe. His research activities are about combining GIS, spatial statistics, geo-simulation and spatiotemporal modeling to further studies related to real estate markets, mobility behavior, accessibility to urban amenities, environ-mental impacts assessment, urban and regional planning. Findings of his research are published in more than 40 academic journals related to urban economics, housing, geography, geographical information science, transportation planning, computer science, environment, health science and regional development. He has edited several books.'

Jean-Claude Thill is the Knight Distinguished Professor of Public Policy at the University of North Carolina at Charlotte. He holds a doctorate in Geography from the Catholic University of Louvain, Belgium. Dr. Thill's multi-prong research has centered on the spatial dimension of mobility systems and their consequences on how space is used and organized in modern societies, statistical and computational methods of spatial analysis, and most recently urban land-use dynamics. Since 2008, he has been Editor-in-Chief of the international journal Computers, Environment and Urban Systems, and serves on the editorial boards of several other regional, national, and international journals of geography, regional science, and spatial systems. He is the Executive Director of the North American Regional Science Council. He received the 1988 Philippe Aydalot Prize, the 1996 Geoffrey J. D. Hewings Ward, and the 2008 David Boyce Service Award from the North American Regional Science Council. He has held faculty positions at Florida Atlantic University, The University of Georgia, and The State University of New York at Buffalo. He joined the University of North Carolina at Charlotte in 2006.

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